Fuels

Expanding Clean Fuel and Feedstock Resources

INTRODUCTION

CLEAN FUELS FOR A SECURE FUTURE

The need for liquid fuels is forecast to be a critical element of this Nation's energy future in the 21st century. The C&PS Fuels Program seeks to ensure the development and demonstration of economically competitive, efficient, environmentally responsible coal-based technologies that produce ultra-clean transportation fuels, utility and boiler fuels, chemicals, and carbon products for metallurgical and industrial applications.

PROGRAM AREAS

- TRANSPORTATION FUELS AND CHEMICALS
- SOLID FUELS AND FEEDSTOCKS
- ADVANCED FUELS RESEARCH

The Fuels Program is driven by three preeminent challenges: (1) improve the environment, (2) strengthen the economy, and (3) enhance our energy security.

In 1996, the transportation sector was responsible for 80 percent of the carbon monoxide, 50 percent of the nitrogen oxides, and 40 percent of the volatile organic compounds of the total man-made air emissions in the United States. Moreover, transportation accounts for approximately 470 million metric tons (MMT) of carbon emissions, or 32% of total U.S. carbon emissions. The Energy Information Administration (EIA) projects that by 2020, total carbon emissions in the U.S. will increase to 1,960 MMT under business-as-usual assumptions with transportation accounting for 690 MMT, or 35% of total U.S. carbon emissions. There is a host of potential regulatory actions that could require major additional reductions in energy-related emissions during the next decade, and some are expected to be very expensive if compliance must depend on conventional fuels. Likewise, restructuring in the electric utility industry will place market pressures on utilities to find low-cost approaches to meeting stringent environmental regulations for potentially hazardous air pollutants.

The EIA also predicts that, by 2020, U.S. petroleum imports (already representing over 50% of consumption) will rise to 65% and increase our negative balance of payments. Currently, the U.S. imports approximately 11 million barrels per day of crude oil and finished products, 50 percent of which comes from the Organization of Petroleum Exporting Countries (OPEC). At current world oil market prices, oil imports cost the U.S. almost $90 billion per year. Projections of brisk growth in domestic and world oil demand substantially change the energy security outlook. Excessive reliance on a single geographic area to satisfy increased world demand for oil creates the potential for oil-importing nations to be vulnerable to supply disruptions and price volatility. Further, petroleum is a finite resource whose production will eventually peak and decline in the face of continually increasing demand. It cannot be known when this peak in production will occur with any degree of certainty. However, current estimates of ultimately recoverable conventional oil (approximately 2.7 trillion barrels) and projected world oil demand have led experts to predict a peak in petroleum production occurring around the year 2015 and declining thereafter. While there may be 2.7 trillion barrels of petroleum more than currently assessed, these additional resources are likely to reduce the rate of decline rather than increase peak production. As conventional oil resource production approaches its peak and eventual decline, there is the risk that the price of oil will rise significantly and permanently. This risk can be minimized through development of fuels from alternative domestic sources.

For the long-term, the wisest policy is to depend on a balanced mixture of energy sources including gas, coal, biomass, opportunity fuels, wastes, and oil. Without new and better technology, the ability to lower emissions will be limited and the costs of energy will increase.

A key emphasis in transportation fuels development is the production of high-quality, clean-burning diesel fuels from both natural gas and coal. The Solid Fuels and Feedstocks program area examines the environmental and economic

benefits of blending biomass and waste feedstocks with coal, develops tailored feedstocks for making premium carbon products, and provides the means to remove trace contaminants from coal. Through Vision 21, advanced technologies for coproducing power, fuels, and chemicals will enable the Nation to use its plentiful fossil resources to fulfill a broader range of energy and chemical feedstock needs while reducing impacts to the environment.

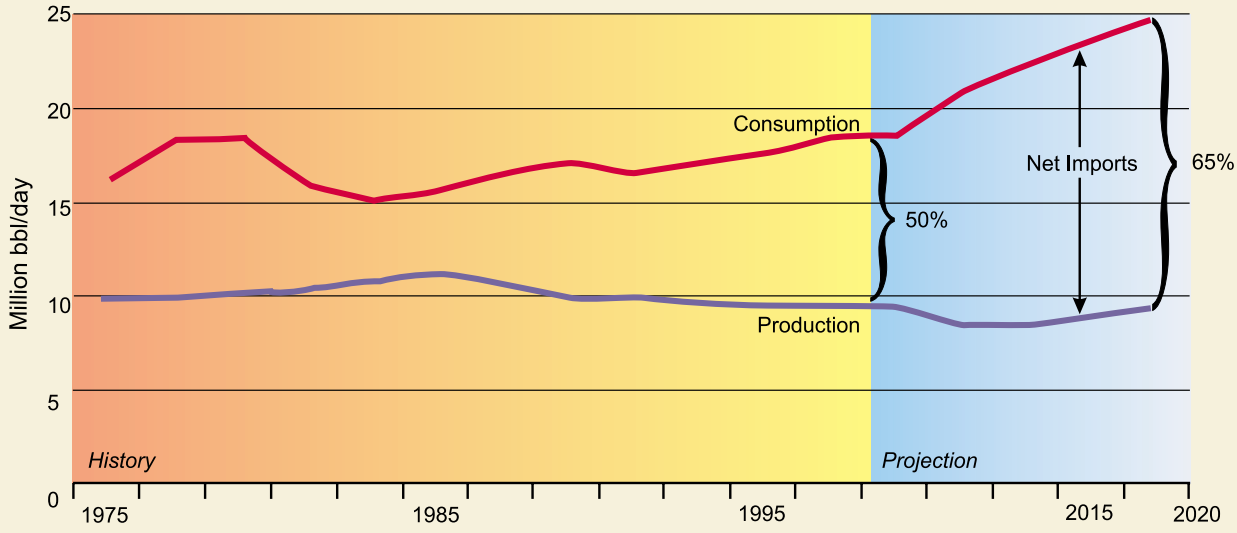
The Program

The C&PS Fuels Program response to these environmental, energy security, and economic challenges is to provide the technical basis for a clean fuels industry capable of producing transportation fuels and chemicals from coal and other carbonaceous, nonpetroleum domestic resources. Specifically, research is focused on developing ultra-clean transportation fuels, feedstocks for power generation that will help to lower emissions, and carbon high-value products. Technology development in these R&D areas will ensure coal's continued role in the Nation's energy future.

The Transportation Fuels and Chemicals program area encompasses several approaches to produce ultra-clean transportation fuels for use in high-efficiency vehicles and light- and heavy-duty trucks. The Advanced Fuels Research program area provides the scientific foundation for technology development in the Transportation Fuels and Chemicals program area, and develops concepts that will help address the "grand challenges" associated with Vision 21. The Solid Fuels and Feedstocks program area involves coal preparation, potential HAPs precursor removal, carbon products development, and carbon recovery.

Research is focused on developing ultra-clean transportation fuels for high-efficiency vehicles and light- and heavy- duty trucks.

EIA – Projected U.S. Crude Oil Production and Consumption



BENEFITS

CUSTOMER BENEFITS

- Protects against price shocks in the transportation fuels arena;
- Dramatically improves the mileage efficiency of transportation vehicles;
- Ensures reliability of fuel supply; and
- Improves economics of fuels, chemical, and power through coproduction.

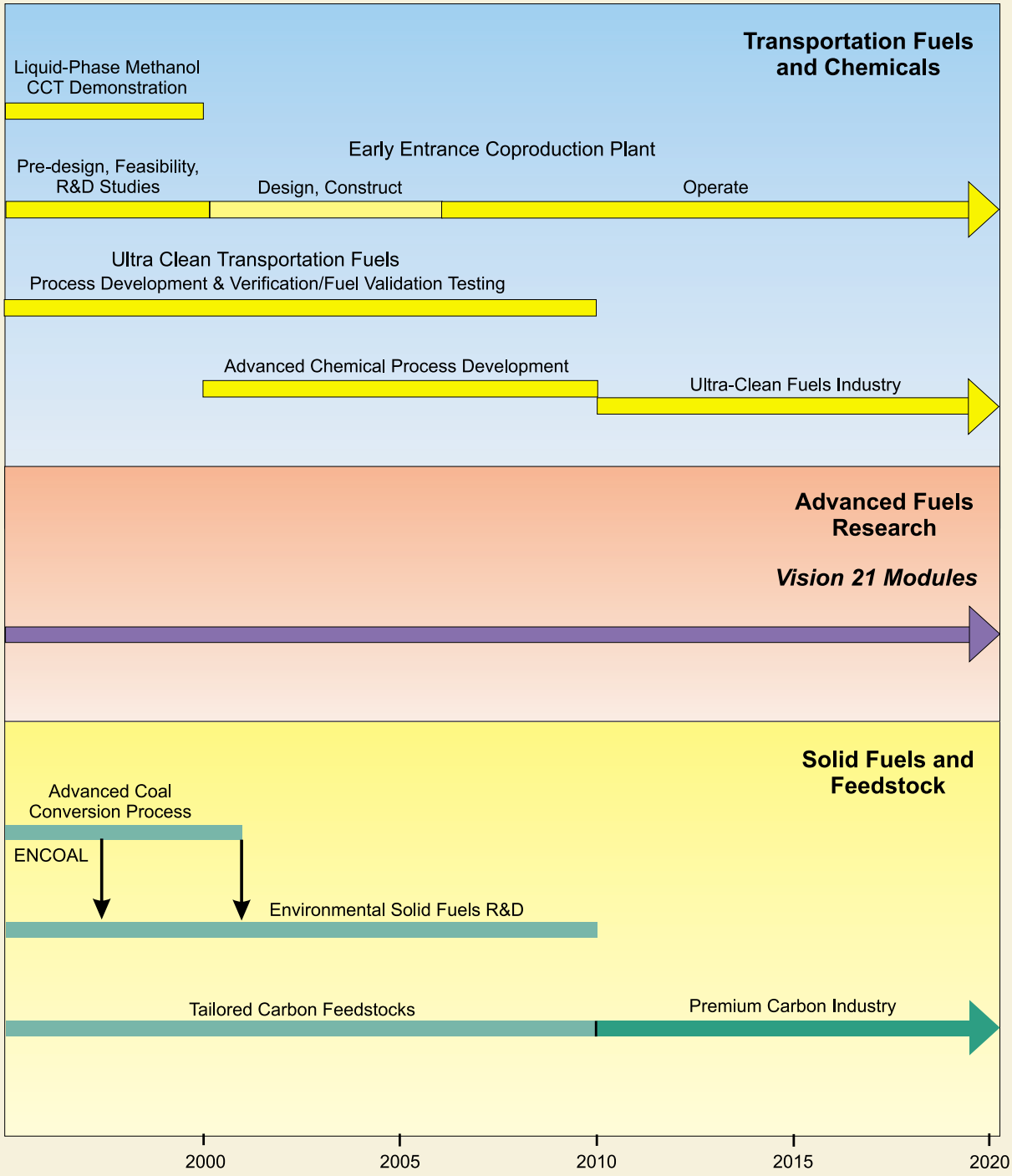
SUPPLIER BENEFITS

- Boosts processing efficiencies of fuels development leading to lower capital and maintenance costs which, in turn, influences supplier economics;
- Provides, through gasification-based coal conversion, a way to store energy from a power plant during off-peak periods when demand is low; and
- Allows for flexibility in affordable, substitute feedstocks for power generation.

NATIONAL BENEFITS

- Reduces emissions through efficiency gains;
- Provides an alternative supply of transportation fuels from domestic resources, thus hedging against security risk; and
- Reduces the U.S. balance of payments.

Roadmap


Transportation Fuels and Chemicals
Liquid-Phase Methanol CCT Demonstration
Early Entrance Coproduction Plant
Pre-design, Feasibility, R&D Studies
Design, Construct
Operate
Ultra Clean Transportation Fuels
Process Development & Verification/Fuel Validation Testing
Advanced Chemical Process Development
Ultra-Clean Fuels Industry
Advanced Fuels Research
Vision 21 Modules
Solid Fuels and Feedstock
Advanced Coal Conversion Process
ENCOAL
Environmental Solid Fuels R&D
Tailored Carbon Feedstocks
Premium Carbon Industry
2000
2005
2010
2015
2020

Drivers

- EPA standards will require cleaner burning transportation fuels in order to reduce urban air pollution, including carbon monoxide, nitrogen oxides, volatile organic compounds, and particulates.
- Environmental and economic incentives will encourage the reduction of solid wastes associated with coal production and utilization.
- The U.S. economy is almost totally dependent on oil for its transportation needs.
- By 2015, it is projected that the demand for petroleum in non-industrialized countries will nearly double, and the U.S. will be importing nearly 60 percent of its oil, much of which will come from the Middle East.
- The high level of imports have worrisome energy security and economic implications, through negative balance of payments and the potential for supply disruptions with the attendant economic dislocations.
- Deregulation will place market pressures on utilities to find low-cost approaches to meet stringent environmental regulations for potentially hazardous air pollutants.
- The expanding export market for cost-effective coal technologies that are attractive to coal-intensive developing countries will lead to the creation of jobs, reduction of trade deficits, and improved regional and global environment.

Goals

- Transportation Fuels and Chemicals

  – Provide the technology base for a clean fuels industry capable of producing transportation fuels and chemicals from coal and other carbonaceous, non-petroleum domestic resources.
- Solid Fuels and Feedstocks

  – Foster the development of advanced technologies to enable the efficient use of coal, biomass, and waste fuels while addressing environmental concerns associated with hazardous air pollutant and greenhouse gas emissions and waste disposal issues.

  – Develop a “coal-based” U.S. carbon products industry.
- Advanced Fuels Research

  – Conduct the fundamental and exploratory research needed to support the fuels and chemical production aspects of Vision 21 technologies and improved methods of producing liquid transportation fuels.

Strategies

- Transportation Fuels and Chemicals

  – Complete demonstration of Liquid-Phase Methanol Clean Coal Technology Demonstration Project. (2001)

  – Advance three-phase slurry reactor technology to cost-effectively produce premium fuels, diesel-fuel blending compounds, or high-value chemicals from coal or natural gas.

  – Deploy one or more Early Entrance Coproduction Plants that demonstrates the feasibility of producing some combination of power, fuels, and chemicals from coal. (2007)

  – Establish fuel industry/government consortiums to identify needs of transportation industry; continue support/participation in engine/vehicle development efforts.

- Solid Fuels and Feedstock

  – Complete demonstration of Advanced Coal Conversion Process Clean Coal Technology Project. (2001)

  – Conduct research on advanced technologies for the reduction of greenhouse gases and for low-cost precombustion control of hazardous air pollutant precursors.

  – Conduct research on technologies to enhance carbon recovery from coal and coal wastes, and improve coal fines processing.

  – Support the industry-led, cost-shared consortium to develop, demonstrate, and commercialize technologies for non-fuel use of coal.

- Advanced Fuels Research

  – Conduct research and early development of improved innovative concepts for Vision 21 modules to produce transportation fuels, chemicals, and carbon products with high efficiency, improved environmental performance, and reduced CO_2 production.

Measures of Success

- To have the capability to produce 2 million barrels/day of premium transportation fuels, blendstocks, and additives. (2020)
- To have the capability to produce, by 2008, ultra clean fuels that will help vehicles meet EPA Tier II Standards (i.e., 0.07g/mi NO_x, 0.01g/mi PM). (2008)
- To deploy commercially-scaleable, fully integrated coproduction plants that demonstrate the technical, economic, and environmental benefits of producing multiple products from gasification-based technology. (2007)
- To increase output of U.S. finished carbon products industry by five-fold, while increasing core domestic employment from 50,000 to 150,000. (2010)
- To have fuel and chemical process modules as components of Vision 21 facilities or as stand-alone plants; meet requirements and schedules of advanced vehicle development program for clean fuels. (2020)

PROGRAM AREAS

TRANSPORTATION FUELS AND CHEMICALS

The Transportation Fuels and Chemicals program area supports R&D technologies to produce ultra-clean transportation fuels, chemicals, and carbon products. The technologies convert coal into liquid fuels and chemicals in two steps. In the first step, coal is gasified in the presence of oxygen and steam to generate a gas containing mostly carbon monoxide and hydrogen (i.e., synthesis gas). In the second step, the synthesis gas, after being cleaned of impurities, is converted into a variety of products. These products include:

- Hydrocarbon fuels, such as gasoline, diesel fuel, and jet fuel.
- Oxygenated compounds, such as alcohol fuels (e.g., methanol), and oxygenated fuel additives (e.g., ethers and esters).
- Premium chemicals, such as olefins and paraffinic wax.

Research within the Transportation Fuels and Chemicals program area is focused on developing clean fuels that: (1) are environmentally superior to those derived from conventional petroleum-based fuels; (2) can supplement the liquid fuel requirements of the Nation's transportation infrastructure; (3) will use the existing transportation fuels infrastructure; and (4) will help engine and vehicle manufacturers achieve higher performance with significantly lower emissions in both conventional and advanced systems. In addition, advanced chemical processes are being developed that lead to greater process efficiencies and lower capital costs.

The base program area research efforts address key technical issues associated with making premium fuels and chemicals, and provides the foundation upon which to pursue initiatives such as the Liquid-Phase Methanol™ Project currently being demonstrated in the Clean Coal Technology Program; the Early Entrance Coproduction Plant initiative that is co-sponsored with Gasification Technologies; and the Ultra-Clean Transportation Fuels initiative, which is jointly sponsored by Transportation Fuels and Chemicals, Natural Gas Processing, and Petroleum Processing.

Projects within the base program areas currently emphasize:

Process Development

- Continued improvements in the three-phase slurry reactor technology where technology advances have shown significant productivity improvements.
- Development of low-cost iron-based catalysts for the slurry reactor, especially for their application and suitability to feedstocks that are low in hydrogen content such as coal, wastes, and petroleum coke.
- Separation techniques for both gaseous and liquid products to remove contaminants.

Product Testing/Evaluation

- Laboratory characterization of product quality, including emissions tests in engines.

LPMEOH™ 80,000 gallon-per-day demonstration unit at Eastman Chemical Company's Kingsport, Tennessee Facility.

Systems Engineering

- Extensive life cycle analyses to identify those areas of fuel conversion processing that offer the best opportunities for CO_2 mitigation.

Concurrently, R&D is underway on novel methods to reduce production of greenhouse gases through process improvements and utilization of multiple feeds such as waste material or biomass. Each of these projects is examining process details within the context of a system that is intended to make a specific product.

Technology Status and Direction. With current technology, the cost of producing coal-derived fuels in stand-alone plants would be about $30 per barrel crude oil equivalent (COE). The cost can be reduced to the $21 per barrel COE target by coproduction of liquid fuels and electric power. Novel three-phase slurry reactor technology is being developed to cost-effectively produce premium fuels, an excellent diesel fuel-blending feedstock, or high-value chemicals using syngas produced from natural gas, petroleum coke, refinery waste, and/or coal. Because of the interest in production of high-quality diesel fuel through the Fischer-Tropsch process, DOE's Office of Transportation Technologies is an important partner with the Office of Fossil Energy in developing fuels and transportation systems.

The following describes some of the key elements of the Transportation Fuels and Chemicals program area's base research and key initiatives that are being emphasized over the next several years:

Ultra-Clean Transportation Fuels Initiative

It is important to coordinate and integrate FE activities that have clean fuels development as their goal, in the most efficient and cost-effective manner. Therefore, FE's petroleum processing, natural gas-to-liquids, and coal-based transportation fuels activities have partnered to form a comprehensive, well-coordinated Ultra-Clean Transportation Fuels Initiative (UCTFI) for producing fuels for ultra-low emission vehicles. This integrated FE activity has the common goal of promoting the production of ultra-clean fuels from a diversity of resources. This partnership will also make more effective use of the skill mix, resources, and synergy among the programs. The result will be more efficient leveraging of Federal Government and private sector resources, and the more rapid commercialization and deployment of these fuels.

During 1999, workshops and meetings were held with several companies and individuals to structure a government/industry partnership that would address the burdens being placed on fuel producers. Concurrently, discussions with DOE Energy Efficiency's Office of Transportation Technologies provided the basis for DOE EE-FE collaboration on a major solicitation that was issued in February 2000. This UCTFI encompasses three R&D areas that will be pursued over five years.

The core part of UCTFI is directed toward systems-oriented R&D projects that lead to the production of sufficient quantities of fuel to validate performance and emissions. Fuels testing will be done in collaboration with DOE Energy Efficiency's Office of Transportation Technologies. The second focus area is on development of advanced unit operations/processes for producing ultra-clean transportation fuels. The third area emphasizes the development of new and innovative emission control systems. In addition, an aggressive supporting research program is being set aside for a National Laboratory partnership that will focus on examining some of the key scientific issues (reaction chemistry, materials, etc.) associated with the conversion of natural gas, petroleum, and coal to ultra-clean transportation fuels. The goal of the UCTFI is to develop and deploy technologies that will produce ultra-clean burning transportation fuels for the 21st century from both petroleum and non-petroleum resources. These fuels will:

- Enable vehicles to comply with future emission requirements;
- Be compatible with the existing liquid fuels infrastructure;
- Enable vehicle efficiencies to be significantly increased, with concomitantly reduced CO_2 emissions;
- Be obtainable from a fossil resource, alone or in combination with other hydrocarbon materials such as refinery wastes, municipal wastes, and biomass; and
- Be cost competitive with current fuels.

Early Entrance Coproduction Plant

The Early Entrance Coproduction Plant initiative examines the feasibility of coproduction technology where transportation fuels, chemicals, electric power, process heat, etc. are coproduced in one facility from various feedstocks. This initiative is part of a joint effort with the Gasification Technologies program. In these studies, teams will pursue industry/government cost-shared research and engineering studies that will be directed toward privately funded design, construction and operation by 2007 of first-of-a-kind commercial facilities that coproduce multiple products. These activities will help industry teams refine their strategies, reduce technical risk, and define economic and environmental requirements.

In Fiscal Year 1999, three projects were chosen for negotiation and two project awards were made. Texaco Natural Gas, Inc. and its team will combine its gasification technology with Rentech Fischer-Tropsch technology to produce high-quality transportation fuels and chemicals from a coal and petcoke. The Dynegy Power Corporation team will evaluate producing power and chemicals from a plant that processes coal and non-coal feedstocks. A third project, Waste Management and Processors, Inc. and its team including Sasol Technology Ltd. and Texaco Global Gas and Power, will assess the economics and feasibility of a plant that converts coal residue into premium transportation fuels and power.

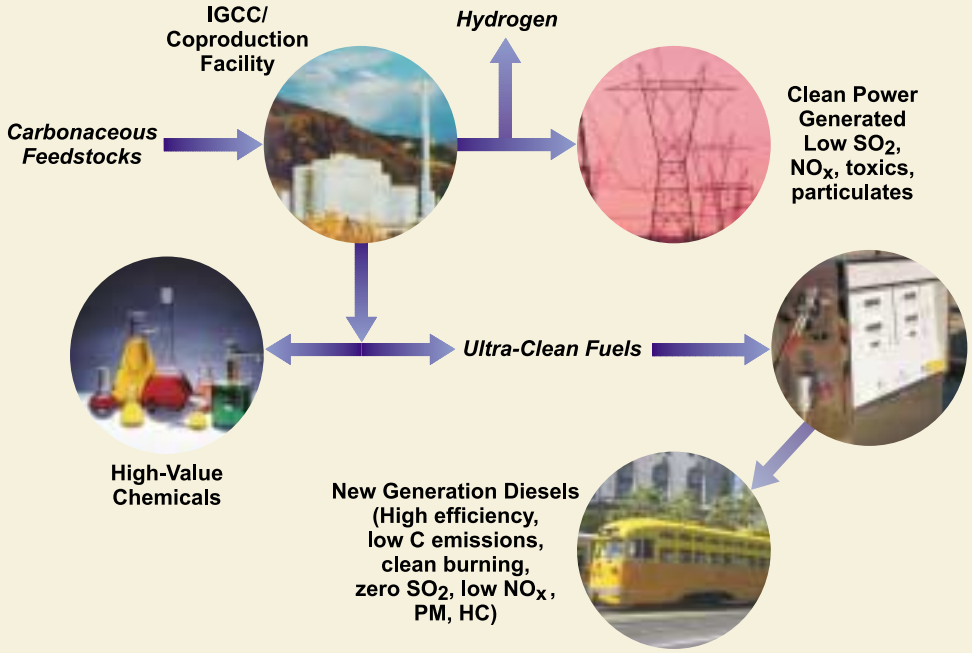
Systems Engineering and Analysis

Engineering and economic analysis are needed to define and prioritize future R&D initiatives to support commercialization activities, both domestic and international. A major emphasis is on performing life-cycle environmental analysis on CO_2 and analysis of configurations that can significantly reduce manufacturing costs.

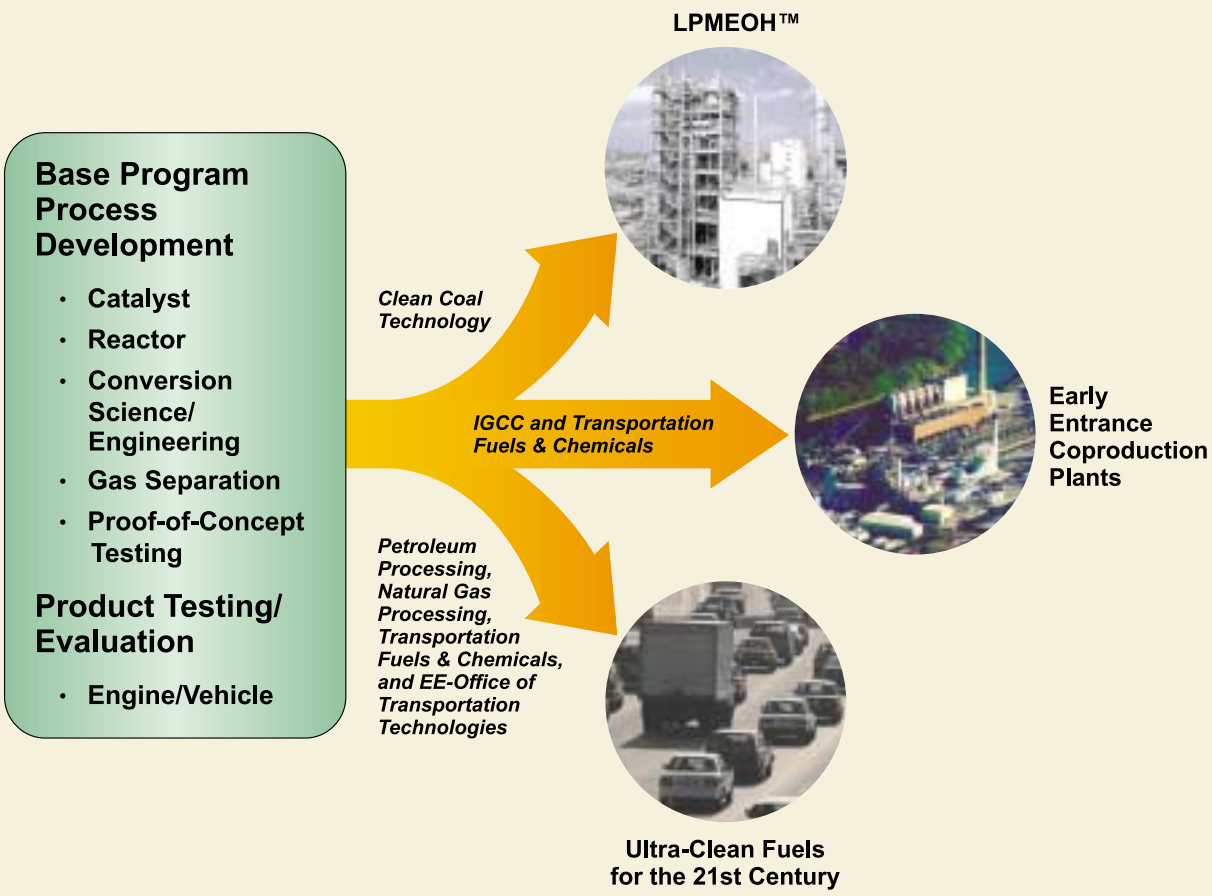
Proof-of-Concept Testing

Proof-of-Concept (POC) evaluations to produce Fischer-Tropsch and other premium, high performance fuels will provide optimum processing strategies and sufficient quantities of materials for engine and vehicle tests. All coal-fuels R&D, which culminates in POC activities and fuel testing, is focused on developing fuels that assist the transportation sector in meeting its future emission requirements. To this end, partnerships have been created with other federal organizations and their stakeholders to facilitate commercial deployment of these advanced, ultra-clean fuels.

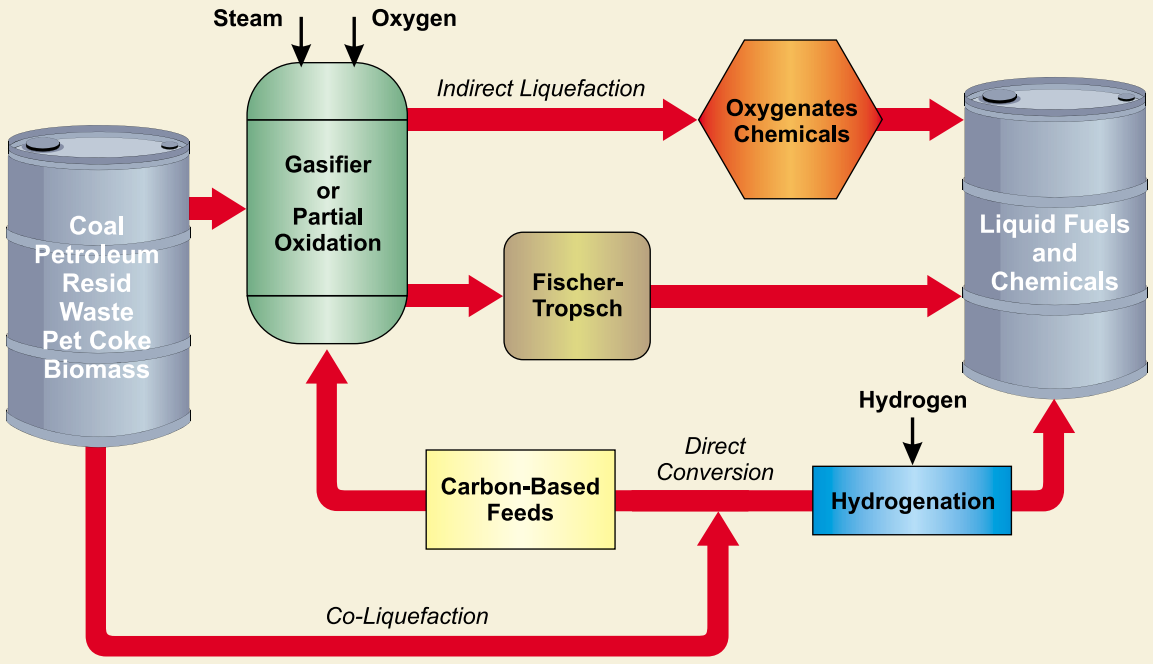
Coproduction Integrated into a Power/Fuels/End-Use System



Transportation Fuels & Chemicals: The Program



Transportation Fuels Conversion Processes



Novel R&D in Coal Conversion

Computation chemistry techniques will be used to more efficiently develop kinetic models of coal conversion processes, which will greatly reduce the laboratory R&D needed to effect process improvements. In addition, R&D will examine innovative hydrogen production technologies that have the potential to provide for both sequestration of CO_2 and significant reductions in manufacturing costs.

Solid Fuels and Feedstocks

The objectives of the Solid Fuels and Feedstocks program area are to: (1) develop and verify innovative processing, handling, and transportation technologies that would improve the overall efficiency, economics, and environmental performance of energy-utilization systems; (2) reduce environmental impacts associated with the generation of greenhouse gases and HAPs from coal utilization; (3) permit greater recoveries of useful energy in mined coal; (4) encourage the recovery of previously lost carbon raw materials from waste piles and tailing ponds; and (5) support the development of a technology that produces premium carbon and industrial products. These technologies would yield a wide range of products that are economically competitive with and result in less environmental impact than competing fuels or products.

The Solid Fuels and Feedstocks program area is focused on activities to develop advanced technologies for the production of environmentally acceptable solid fuels and tailored carbon feedstocks. The product of Solid Fuels and Feedstocks research consists of a suite of advanced technologies that are highly efficient and cost-effective in converting raw solids into finished fuel and feedstocks suitable for customer needs. These technologies include a wide variety of processes that improve production, upgrading, handling, and transporting of various solid fuels. The range of solid fuels available for use is extensive and includes coal, alone and in combination with biomass, rubber, plastics, industrial residues, municipal solid wastes, and other solid wastes. Feedstocks are based on solid fuels that can be converted to high-value carbon-containing products.

Clean Coal Technology Program

Two Clean Coal Technology projects addressed the conversion of low-energy-density, low-sulfur western coals into high-energy-density, very low-sulfur products. ENCOAL's demonstration of the Liquids-From-Coal (LFC®) process successfully completed operations in July 1997, and the technology is moving toward commercialization. During the demonstration, nearly 260,000 tons of raw coal were processed into 120,000 tons of solid process derived fuel (PDF®) and more than 121,000 barrels of coal derived liquid (CDL®). A cross section of customers consumed almost all of the product.

Western Syncoal Partnership's demonstration of the Advanced Coal Conversion Process (ACCP) continues to operate under an

Rosebud SynCoal Partnership's Advanced Coal Conversion Process for upgrading low-rank subbituminous and lignite coals.

8-year contract to supply a high-energy-density, low-sulfur solid Syncoal® fuel to Montana Power's 330-MWe Colstrip No. 2 unit using a dedicated pneumatic feed system. Through fiscal year 1999, the ACCP facility had processed over 2.3 million tons of raw coal to produce over 1.5 million tons of Syncoal®.

Environmental Solid Fuels

Research in this area is developing innovative methods for recovering useable fuels from materials that otherwise would be discarded at coal cleaning plants or utility power stations. Projects address the estimated 2 to 3 billion tons of coal fines that lie in waste impoundments at coal mines and washing plants around the country, the approximately 30 million tons of coal that is currently being wasted into ponds each year by active mining operations, and the millions of tons of unburned carbon found in power plant fly ash landfills. Technologies are also being developed that combine coal and biomass or municipal solid waste into clean-burning fuels. Moreover, under development is a method for removing mercury from coal before it is burned, preventing the mercury from being released to form a hazardous air pollutant.

Other research in this area that will result in the more efficient use of solid fuels includes proof-of-concept (POC)-scale testing of a selective agglomeration process that uses a new mixing device (tubular processor); pilot-scale testing of an electrostatic separation process for dry, fine-size coal; and POC-scale testing of an advanced flotation control system.

The Solid Fuels and Feedstocks Program investigates making premium carbon products from coal, such as high-quality graphite electrodes. (Courtesy of the Carbide/Graphite Group, Inc., Pittsburgh, PA.)

Industrial-scale testing of an advanced technology will also be conducted for the production of carbonized slurry fuels for power production from coal, biomass, and waste. Work will also continue on the development of a national coal-quality database on trace elements and cooperation with a broad-based, utility-sector consortium for coal utilization.

Tailored Carbon Feedstocks

Premium carbon feedstocks and products are being developed by an industry-led, cost-shared consortium that will develop, demonstrate, and commercialize technologies for non-fuel uses of coal, such as:

- High-value premium carbon and graphite products;
- High-strength, lightweight materials for improving fuel efficiency/reducing weight of vehicles;
- Advanced feedstocks to reduce hazardous air pollutants, such as mercury;
- Improved rechargeable batteries;
- Fuel cell applications;
- Chemically-tailored carbon molecular sieves;
- Adsorbents for water and air pollution control;
- Specialty chemicals and coke; and
- Materials for heat-resistant applications.

Advanced Fuels Research

The goal for the Advanced Research program area is to lead the long-term development of advanced fossil energy technologies that will improve the Nation's economy, enhance energy security, and address relevant environmental and global climate change issues. The objectives are to discover and apply new understandings of the chemistry and physics of carbon conversion to determine and overcome technical barriers that prevent the development of economically competitive, efficient, and environmentally responsible technologies. These technologies would be designed to close the carbon cycle while ensuring sustained use of domestic carbon sources for the production of economic transportation and boiler fuels, chemicals, and high-value carbon products.

Advanced Fuels Research encompasses research activities that develop fossil-resource technology for transportation fuels, chemicals, and carbon and industrial product markets. These technologies must not only provide increased energy security by using domestic resources in an environmentally benign manner, but they also must be consistent with global climate change strategy, which might require complete control of the carbon cycle. The research centers on developing, over the longer term, significantly improved and innovative technologies that produce economically competitive fuels with minimal environmental impact and with reduced by-product CO_2 production. Examples of such technologies include: (1) innovative, less severe, coal-derived fuel technology that produces fuels at lower costs with less energy usage; (2) hybrid, renewable and fossil energy technology as part of Vision 21 concepts to produce fuels, electricity, chemicals, and carbon products with increased environmental performance and with less CO_2; (3) computational methods to improve catalyst development and experimental evaluation; and (4) bioprocessing systems that produce liquid transportation fuels with less CO_2 production. These technologies will provide the longer-term modular processes to be used in Vision 21 plants, which would produce energy and fuels products in a manner consistent with global climate change strategies.

Program Success

Fuels Research at LaPorte, Texas Plant

As the research progresses in the base program from laboratory to bench-scale experiments, the advances in specific areas of the fuel production system are incorporated into production of specific products at the LaPorte, Texas proof-of-concept unit. This approach has worked very successfully over the past fifteen years, as exemplified by the Liquid-Phase Methanol Process (LPMEOH™), whereby technical viability was proven at LaPorte and is now being demonstrated at commercial scale by the Eastman Chemical Company. More recently, successful operations at LaPorte included production of Fischer-Tropsch liquids and dimethyl ether, both of which are of interest to industry for their potential use as premium fuels.

Air Product's LaPorte coal liquefaction test facility contributes to RD&D efforts that ensure future availability of clean, affordable coal-derived fuels.